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Optimum Temperature for Growth of Juvenile Bluegills

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ABSTRACT: Juvenile bluegills, *Lepomis macrochirus* (initial weight: 1 to 8.0 g), were individually marked and fed to excess during a 30-day constant temperature test; day length was 16 h. Fish were tested at temperature intervals of 2° from 20 to 30°C. The highest specific growth rate occurred at 30°C (2.389/day); however, growth rates of only the groups held at 20 and 30°C were statistically different from the rate for the group held at 30°C.

Poikilothermic animals, such as fish, are directly affected by environmental temperature. Man's manipulation of the environment, either deliberately or indirectly, has resulted in disruption of the natural temperature cycles in many bodies of water (Parler and Krenkel 1969). Fish have optimal physiological ranges of thermal tolerance within which maximum growth and activity occur (Fry 1951). To ensure that temperature effect on growth is actually the variable being measured, one must regulate food, oxygen, and space.

This report presents results of growth studies conducted for 30 days on juvenile bluegills (*Lepomis macrochirus*) under conditions of constant temperature. The bluegill is a nearly ubiquitous species in the United States (Eddy 1969), indicating that its temperature tolerance must be wide. The world record bluegill from Alabama weighed 3.155 kg (4 lb 13 oz) (World Almanac and Book of Facts 1975), whereas the Minnesota record is 1.976 kg (3 lb 13 oz) (Minnesota Department of Conservation 1975). The longer growing season in southern than in northern waters and the increased availability of food in the warmer southern waters probably account for the difference in size of the record fish from the different areas.

Previous physiological studies indicate an optimum temperature near 30°C. Morgan (1951) reported that bluegills are most active between 25 and 30°C and that they become lethargic at 30 to about 35°C. He further reported that bluegills appear to grow at a nearly constant rate between the lengths of 5.5 and 10.0 cm; thereafter growth slows.

Neill and Magnuson (1974) determined from field tests that young bluegills preferred temperatures between 29.4 and 31.3°C.

Materials and Methods

Juvenile bluegills weighing 1 to 8 g were obtained from the U.S. Fish and Wildlife Service hatchery at Lake Mills, Wisconsin. They were maintained for 1

month at 20°C before testing and were fed a combination of Glencoe Mills trout food and frozen brine shrimp (*Artemia salina*). All holding and testing were done in Lake Superior water (Biesinger and Christensen 1972). During the holding period a 1-h formalin treatment was given on a flow-through basis twice weekly, but no treatment was used during the test.

Tests were conducted in a series of flow-through aquariums and temperature was controlled by a water bath (as described in Hokenson et al. 1977). Test chambers contained 14 liters of water, with a flow rate of about 100 ml/min and a mean detention time of 3.3 h. Tanks were not aerated, but entry of the water into the tanks near the bottom at one end and its outflow at the top on the other end aided in mixing the water. Temperatures were tested in 2° increments from 20 to 30°C, and were monitored continuously by multipoint recorder and verified daily by a calibrated mercury thermometer. Dissolved oxygen was measured periodically in all tanks by the Winkler method (American Public Health Association et al. 1971).

Fish were individually marked by using the cold brand liquid nitrogen technique described by Mighell (1969). Duplicate lots of five marked fish and one unmarked fish were used at each temperature. Bluegills were anesthetized with Finquel,¹ branded, and assigned to the tanks by a stratified random method.

Fish were fed to excess three times daily on week days and once a day on weekend days. Tanks were cleaned by siphoning twice daily (once during the weekends). Fish were not fed for at least 16 h before they were weighed. After all tanks had reached test temperature, fish were weighed to the nearest 0.01 g by blotting the fish on a cloth towel, placing it in a preweighed beaker, and reading the weight on a rapid weighing balance. Initial test weights were 1.8 to 8.0 g. This procedure was repeated

¹The U.S. Environmental Protection Agency (EPA) neither recommends nor endorses any commercial product; trade names are used only for identification.

at the end of 14 days and again at 30 days. Weight gains reported are for the 30-day period at constant temperatures.

Statistical analysis of the data included a two-way analysis of variance between logs of individual fish-weight changes during the two time periods to determine if all growth was in log phase. Specific growth was determined by the formula $\ln W_t - \ln W_0 = g/t$ or $\ln t = 100 =$ specific growth for 100 days for each fish, where $\ln$ = natural logarithm; W_t = final weight of fish at the end of the time interval; W_0 = initial weight of fish at the start of the time interval; g = mathematical term used directly in the calculation of t by biological statistics (t is a unitless decimal for t defn. of time interval); t = number of days to the end of the time interval, and $\ln$ = start of the time interval in days from the start of the experiment. These exposure sets were compared in a one-way analysis of variance, and Tukey's test was used to find the difference from the highest mean at the 95% level (Steel and Torrie 1960). A linear regression analysis of specific growth vs. initial weight of all fish was also performed.

Results and Discussion

The maximum excursion from the desired temperature never exceeded 0.5°C, and oxygen concentrations were always above 75% saturation. No temperature-caused mortality occurred at any of the exposure temperatures. Three fish died during the experiment — one had been injured in branding and two jumped out of the tanks. Each of these fish was from a different exposure group; because the remaining fish were individually marked, the information from the surviving fish could be used with little loss of statistical efficiency. Statistical analysis of the two growth periods showed that the test animals remained in the same growth phase during the entire experiment. Means and ranges of specific growth for all fish surviving the experiment are shown for each temperature in Table 1. The highest mean specific growth rate (3.35%/day) was at 30°C.

A physiological preference near 30°C was indicated by several earlier studies (Morgan 1961; Neill and Magnuson 1974; Beltinger 1974; Banner and VanArman 1975). This study confirms, under controlled laboratory conditions, that the preferential and optimum growth temperatures are very close. Bluegills are markedly territorial and it was noted early in the test that certain large individuals appeared to be maintaining control over a large part of the test chamber. It was also noted that the larger fish did not prevent the smaller fish from feeding if the food was supplied in the area occupied by the smaller fish. Later, most of the food was distributed in the tanks in amounts relative to the number of fish in each area of the tank. Visual observation seemed to indicate that there was increased growth by the larger fish at the expense of the smaller ones, but a regression

Table 1. Temperatures and growth rates of test groups of bluegill.

Mean temperature (°C) (standard deviations in parentheses)	Specific growth (%/day)	
		Range
20.04 (0.11)	0.90	1.20-0.60
22.02 (0.06)	1.25	2.01-0.70*
23.93 (0.10)	1.50	2.10-0.64
26.06 (0.08)	1.77	2.34-1.03
28.02 (0.09)	1.99	2.55-1.02*
30.10 (0.09)	3.35	3.86-1.35*
31.00 (0.13)	1.81	3.03-1.13
32.30 (0.14)	1.80	3.74-1.30
33.97 (0.17)	1.17	3.43-0.87

* Eleven fish; other groups consisted of 12 fish.

analysis of initial weight vs. specific growth gave a correlation of only 0.36, which is insignificant. When Tukey's test (Steel and Torrie 1960) was used to test the difference between the maximum growth temperature and other test temperatures, only the specific growth rates at 20 and 30°C were found to be different from the maximum. Inspection of the data reveals a break in the curve at 20 and 30°C and a rather large variation at 34°C, which probably accounts for the lack of differences from the maximum. Ability to grow satisfactorily over a wide range of temperatures is an important factor in the wide distribution of the bluegill.

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